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Conservation and Protection Conservation et Protection

A State of the Environment Fact Sheet

Contaminants in Canadian Seabirds

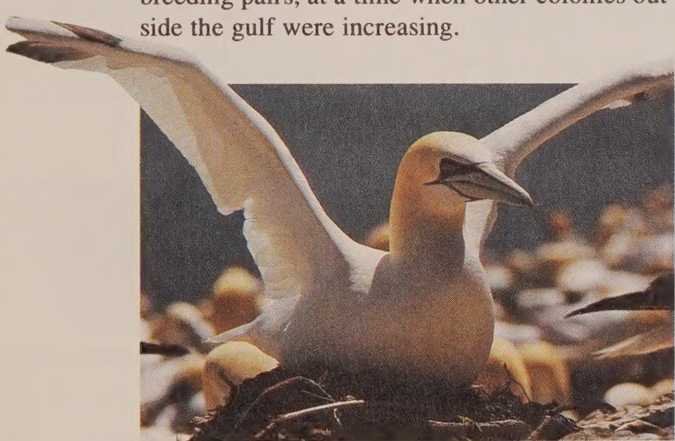
The decline of the Northern Gannet on Bonaventure Island

Bonaventure Island in the Gulf of St. Lawrence is famous for its spectacular bird life. Among the many seabirds that find refuge there is the Northern Gannet, which returns to the high sandstone cliffs of the island each March to breed and to raise its young.

About 21 000 of the 40 100 pairs that make up the North American population of Northern Gannets nest at the Bonaventure colony. There, for centuries, the sleek white birds with their startling blue eyes have laid their single egg and tended their helpless offspring. There, generations of young gannets have taken their first plunge from the nest site to the sea below, as the young birds try their wings for the first time.

The population of the Northern Gannet colony on Bonaventure Island declined nearly 25% from 21 200 breeding pairs in 1966 to 16 400 pairs in 1976

In the late 1960s, fewer and fewer young gannets were taking that first tremendous leap. The population, which had been slowly recovering from human encroachment and hunting since it came under legal protection in 1917, began inexplicably to decline. Between 1966 and 1976, the population of the Northern Gannet colony declined nearly 25% from 21 200 to 16 400 breeding pairs, at a time when other colonies outside the gulf were increasing.



Roy Webster

A Northern Gannet

Highlights

- In the 1960s, Canadian scientists observed birth defects, thin eggshells, and declining populations among birds whose diets were known to be contaminated by synthetic organochlorine pesticides.
- The Canadian government restricted major uses of these long-lasting pesticides and industrial compounds in the 1960s and 1970s.
- Since 1968, Canada has monitored levels of organochlorines in the marine environment, using seabird eggs.
- Levels of DDE have declined on all three coasts, but not significantly so in the St. Lawrence estuary. PCB levels have declined in most sampled locations, but have remained about the same in the St. Lawrence estuary and off western Vancouver Island. Dieldrin levels have declined in most locations, but other organochlorines have shown no consistent pattern.
- Recently high levels of dioxins and furans have been detected in seabirds (Pelagic and Double-crested Cormorants) from the Strait of Georgia.
- Organochlorine residues in seabirds are highest in the St. Lawrence estuary and parts of the Gulf of St. Lawrence.
- The declines in levels of residues of various restricted organochlorines show that controls on use have effectively reduced pollution in areas near sources, but they have had less impact on background levels in the ocean.

The decline of the gannet population led scientists to investigate the levels of toxic compounds in gannet eggs

Ornithologists, concerned about the decline, noticed that many birds were producing eggs with very thin shells: a few eggs were completely lacking the outside cover of the eggshell. Many eggs either broke or disappeared; others simply failed to hatch.

In its search for the reasons behind the shrinking population, the Canadian Wildlife Service collected gannet eggs from the cliffs of Bonaventure Island and analyzed their contents. The analyses revealed high levels of persistent contaminants.

The organochlorine contaminants

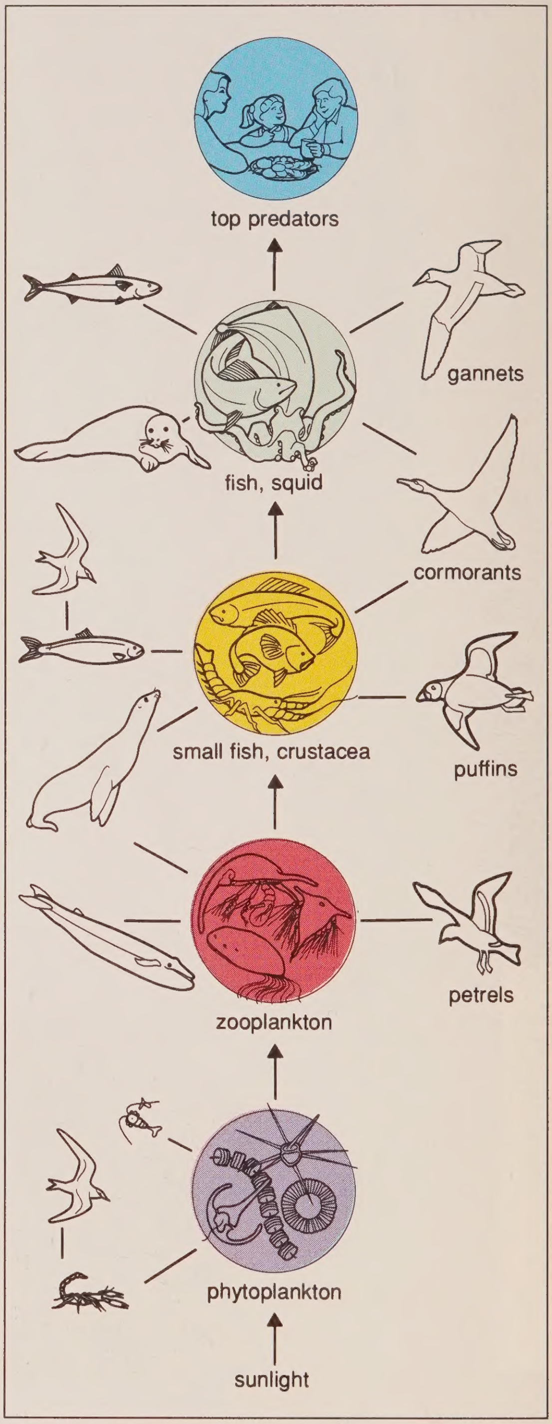
The persistent substances found in the gannets' eggs belong to a group of humanmade organic chemicals known as *chlorinated hydrocarbons* or *organochlorines*. (These terms are used interchangeably in this fact sheet.) This group includes the first generation of synthetic pesticides, the fat-soluble organochlorine pesticides, such as dichlorodiphenyltrichloroethane (DDT), dieldrin, chlordane, heptachlor, toxaphene, and mirex; and fat-soluble industrial compounds, such as polychlorinated biphenyls (PCBs) and chlorobenzenes. The chemical structure of these parent compounds can be altered by sunlight and by microbial and other processes in the environment to form new products, which may be more or less toxic and persistent than their parents. For example, dichlorodiphenyldichloroethylene (DDE), a metabolite (breakdown product) of DDT, is much more persistent than DDT. The group also includes compounds such as the chlorinated dioxins and furans. In Canada some dioxins and furans are produced inadvertently in the chlorine bleaching process used at pulp and paper mills. Others are trace contaminants in chlorophenols, chemicals which had been used extensively as wood preservatives, particularly in British Columbia.

It is the persistence of organochlorines and the fact that they bioaccumulate that make their release into the environment so hazardous

It is the persistence of these compounds and the fact that they are capable of accumulating to dangerous levels in living things that make their release into the environment especially hazardous.

The concentration that an organochlorine will reach in an organism depends on many factors but, in general, the greater the environmental

Figure 1
A simplified marine food chain. Organisms whose food is obtained from plants by the same number of intermediate steps (or links in a food chain) belong to the same "trophic level." The diagram shows the trophic levels of four types of seabirds.



contamination and the higher the animal is on the food chain (Figure 1), the more contaminants it stores (Figure 2). Animals at the top of several food chains — this includes people as fish-eaters and meat-eaters — are likely to store the highest concentrations.

High concentrations of stored organochlorines represent a stress on individual organisms, on populations, and on ecosystems. The severity of the stress varies according to the exact organochlorine or combination of organochlorines involved and the duration of the exposure. The effect that the stress has on the organism will vary according to factors such as the individual's age and state of health. Concern about the accumulation and concentration of organochlorines in living things, including people, (bioconcentration) led to restrictions on many of these substances in many countries, including Canada (see box on p. 6). Understanding of long-term effects of current environmental levels of contaminants on people is limited.

Research into the chronic health effects of stored organochlorines has most often involved wildlife species in contaminated areas. High levels of DDE and dieldrin have been associated with eggshell thinning, reduced breeding success, and declines in numbers of seabirds in many parts of the world. In Canada, studies of fish-eating birds nesting in the Great Lakes area also

J. Foley

Analyzing egg contents

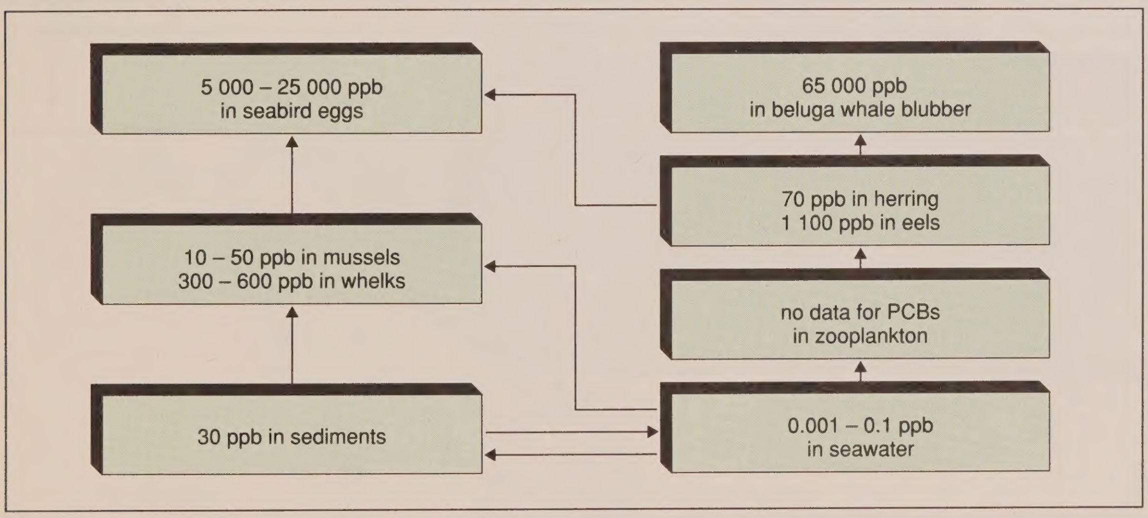
showed that stored organochlorines reduced breeding success. In addition, some studies have associated high levels of PCBs in fish-eating birds with birth defects, interference with liver function, tumours, skin lesions, and reduced growth rates.

Studies of fish-eating birds have shown that stored organochlorines have interfered with breeding success

Organochlorines in the marine environment

Organochlorines reach the ocean by several pathways, particularly through the atmosphere (Figure 3). All persistent chlorinated hydrocarbons that are not in airtight containers eventually evaporate and prevailing winds carry some of them out over the sea, where wind, rain, or snow deposit them on the water surface. In addition,

Figure 2
In the St. Lawrence estuary, PCBs, although present only at low levels in seawater, accumulate in marine organisms to higher concentrations.



organochlorine compounds can be carried to the coast by rivers and swept offshore by ocean currents.

Organochlorines are hydrophobic, meaning that they are virtually insoluble in water. Consequently, rather than remain dissolved in water, they adsorb onto surfaces of organic particulate matter that is suspended in water or in sediments and onto surfaces of living organisms. From the surfaces, the organochlorines may move into the organism and lodge in fatty tissue in animals and plants. These chemicals are also eaten by animals in their food. Thus, in complex marine food chains, which generally have many trophic levels, organochlorines may be thought to flow from the water into each trophic level, and to flow from one level (prey) to the next (predator) in increasing quantities. Animals that filter large amounts of water to feed (e.g., oysters) or breathe (e.g., fish) have faster rates of uptake of these chemicals from water. Animals high on the food chain, such as gannets, obtain almost all their contaminant burden from their prey. Organisms that contain significant amounts of fat have a higher storage capacity.

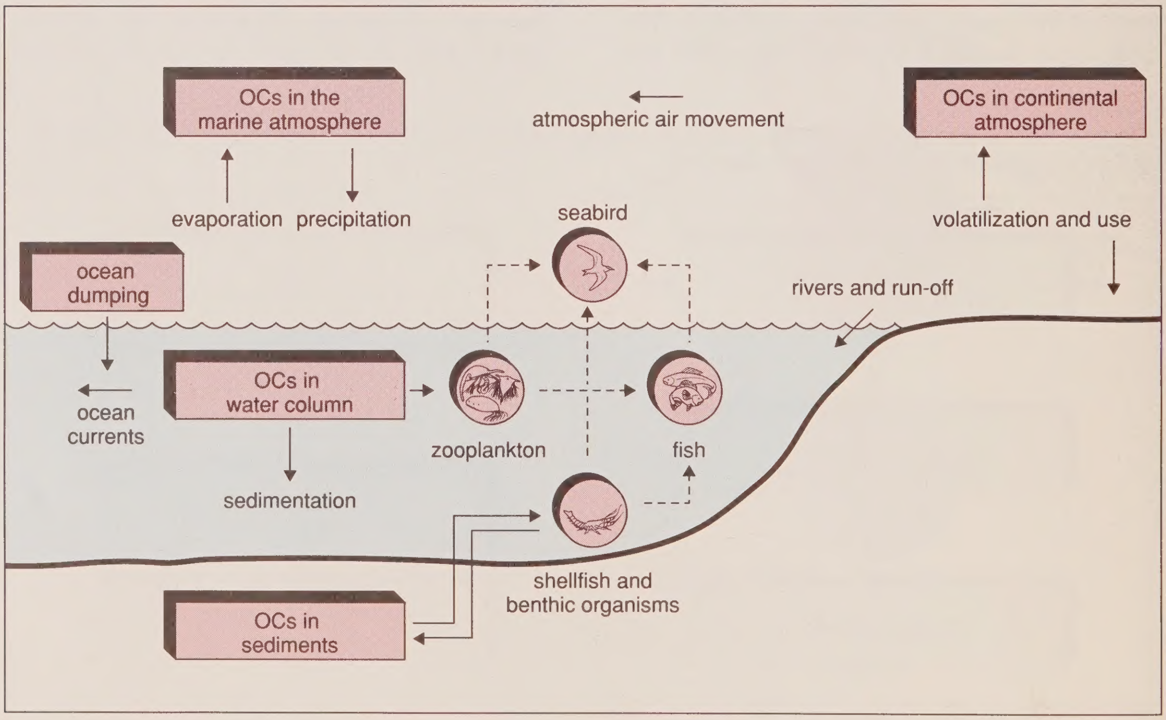
Monitoring organochlorines in the marine environment

Canadian scientists have studied the distribution of contaminants in the Canadian marine environment mainly by monitoring the levels of parent compounds and metabolites in different components of the food chain and interpreting these patterns. Monitoring the changes in the same component (e.g., a seabird egg) over time allows them to judge whether environmental levels of a contaminant are rising or declining.

Colonial seabirds are good monitors because they feed relatively high on the food chain and can be conveniently sampled at their breeding sites. Because they are long-lived animals, there is a greater probability that they will show subtle chronic effects of toxic substances. Also, levels of pollutants among individuals in a seabird colony seem to vary less than in fish and mammals.

Because female seabirds eliminate pollutants through their eggs, the eggs provide an easily collected sample for monitoring purposes.

Figure 3
Movement of organochlorines (OCs) into and within the marine ecosystem



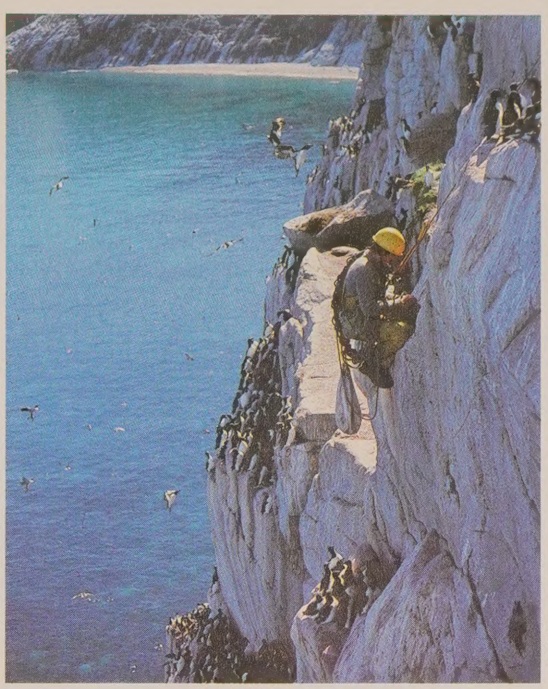
If fresh eggs are taken early in the breeding season many birds will lay replacement eggs. This minimizes the effects of the research on populations. Alternatively, researchers may collect and analyze unhatched eggs at the end of the season. (However, this may result in a biased sample if eggs have failed to hatch because of the pollutants that they contain.)

Surveys of seabirds, 1968–89

Seabird surveys initiated in the 1960s have measured levels of environmental pollutants in seabirds on the Atlantic, Pacific, and Arctic coasts of Canada (Map 1). A formal monitoring program, which involves the collection of eggs at fixed sites and time intervals, has operated on the Atlantic coast since 1968, and a sister program began in 1985 on the Pacific coast, where transport of researchers to the seabird colonies was more difficult to arrange.

The chemists who analyze the contaminants in the eggs have been looking for organochlorines and mercury, a naturally occurring heavy metal that becomes toxic at higher than normal concentrations.

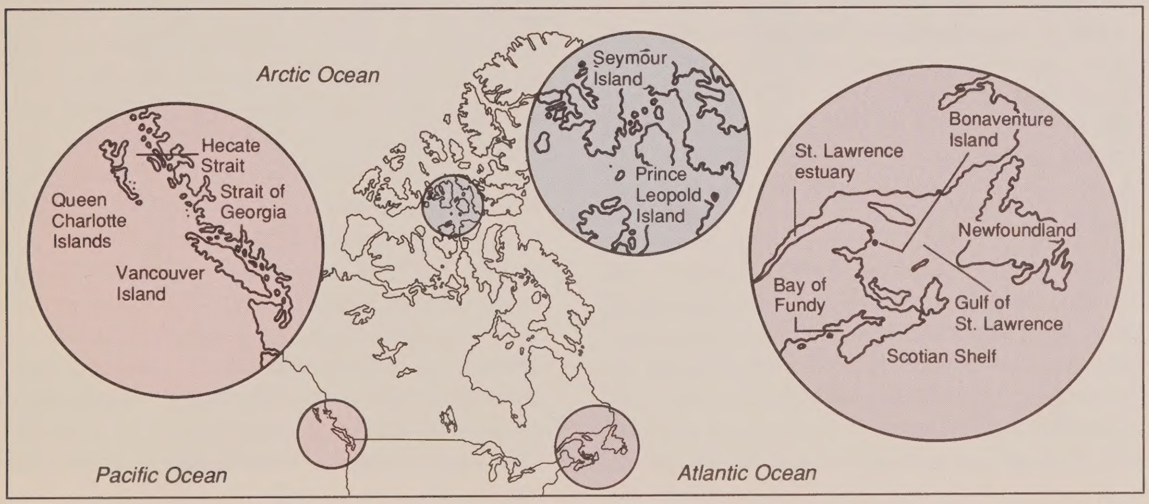
For most organochlorines and mercury, concentrations dangerous to the birds are very small, usually less than 100 parts per million (ppm). In the case of the most toxic dioxin, 2,3,7,8 tetrachlorodibenzo-p-dioxin (2378-TCDD), levels less than 1 part per billion (ppb) — which can be thought of as less than one grain of sand in an Olympic-size swimming pool — may be hazardous. Chemical analysis requires sophisticated techniques and is expensive, and as a result the number of eggs that can be analyzed is limited.



D. Noble

Collecting seabird eggs for monitoring

Map 1
The marine areas where the Canadian Wildlife Service has surveyed seabird eggs for persistent contaminants



Other naturally occurring metals that may be increasing in the marine environment, such as lead and cadmium, which tend to accumulate in the bone and kidney respectively, have been measured more recently, although the number of tissue samples analyzed is still small. Environmental levels of cadmium, lead, and mercury are increased by various manufacturing and resource-extraction processes and exhaust from internal combustion engines that run on leaded gas.

What we know because of the surveys and monitoring programs

The contaminants

PCBs, DDE, toxaphene, dieldrin, mercury, hexachlorobenzene (HCB), oxychlordane, DDT, dichlorodiphenyldichloroethane (DDD), heptachlor epoxide, hexachlorocyclohexane (HCH), mirex, chlordane, and nonachlors were detected in most samples. The oxychlordane, heptachlor epoxide, chlordane, and nonachlors found occur

A chronology

The PCBs first came into use in 1929 and the organochlorine pesticides in the 1940s and 1950s. PCBs had a wide range of uses, primarily in electrical and heat transfer systems. No special precautions were thought to be necessary when disposing of products containing PCBs. DDT and related compounds were applied widely in pest control operations, sometimes sprayed from the air over large areas. Indeed, partly because of its chemical stability and low acute toxicity to mammals, DDT was welcomed as the answer to global problems of insect-borne disease and insect damage to crops.

In the late 1960s, specialists as well as the public came to realize problems of generalized environmental pollution due to use of chlorinated hydrocarbons. As a result, Canada restricted various uses of DDT, aldrin/dieldrin, HCB (hexachlorobenzene), and heptachlor in 1969-71, major uses of toxaphene in 1970 and 1980, non-electrical uses of PCBs in 1977, and most uses of chlordane in 1978. (Mirex was never registered for use in Canada.) The United States and European countries also prohibited many uses of organochlorines at about the same times.

As concern about the dangers of organochlorines to the environment increased, Canada and other countries introduced restrictions on their use

Countries outside North America and Europe have been slower to restrict the use of organochlorine pesticides, and the continued use of these compounds in Latin America may be the source of some of the contaminants in the Canadian environment.

For the few situations where organochlorine pesticides are still allowed in Canada, more effective and less persistent substances are being developed to replace them. Federal and provincial authorities have worked to eliminate most uses of the more persistent substances and only very restricted and controlled uses remain (e.g., lindane seed-treatment on canola and the use of chlordane and aldrin for underground termite control in structures by provincially licensed pest-control operators).

PCBs are also being phased out. In 1988, the Canadian Council of Ministers of the Environment pledged to remove all PCBs from use in Canada by 1993. At the same time, the federal government agreed to lease mobile PCB incinerators to destroy federal PCB wastes across Canada.

Monitoring programs involving seabirds have alerted Canadians to environmental contamination by dioxins and furans. The seriousness and sources of the contamination are still under investigation. Contributing sources to this contamination are chlorophenol wood treatment chemicals used in sawmill operations and pulp and paper mills employing chlorine bleaching. Recently, new federal and provincial regulations have been proposed that will require mills to make significant reductions in levels of these compounds in their effluents. The industry has also initiated measures to reduce their discharges by substitution of the chlorophenol wood treatment chemicals and modifications to the pulp-bleaching processes.

as breakdown products of chlordane and heptachlor, which are similar insecticides. DDD is, like DDE, a metabolite of DDT.

Figure 4 shows the relative concentrations of these compounds in an Atlantic Puffin egg collected at Great Island off the coast of Newfoundland in 1988.

Geographic distribution of pollutants

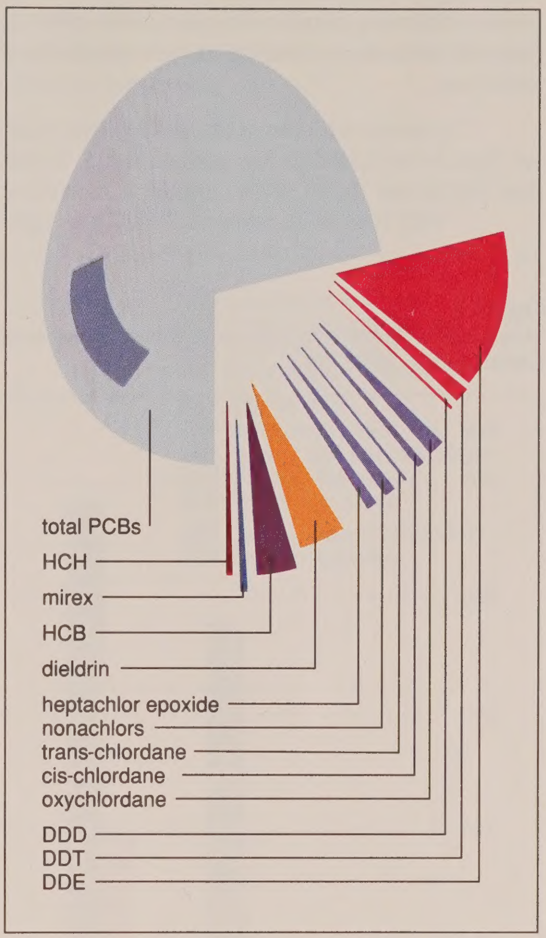
Atlantic coast — On the Atlantic coast, contaminant residues in seabirds are generally highest in the St. Lawrence estuary and gulf, lower in the Bay of Fundy, and lowest off the coast of Newfoundland and southern Labrador. The continuing presence of organochlorines in seabirds breeding in remote Atlantic colonies indicates that long-range transport — in the atmosphere or by ocean currents — is occurring.

Judging by contaminant levels in seabird eggs, the St. Lawrence estuary is one of the most contaminated marine environments in Canada. The estuary receives the outflow from the heavily populated Great Lakes and St. Lawrence River watershed, carrying with it the effluents of industries lining the shores. Despite the differences in diet and migratory patterns, eggs of all three species tested in the estuary — Double-crested Cormorants, Herring Gulls, and Razorbills — were all quite highly contaminated, suggesting that local conditions were responsible.

Outside the estuary, in the Gulf of St. Lawrence, levels of organochlorine contaminants differed among sampling locations and sampled species. In this area, differences in contamination appeared to be related to differences in diet: species such as gannets, which feed on large schooling fish such as mackerel and herring, contained the most contaminants. Terns, feeding on small fish and pelagic zooplankton, were the least contaminated.

High Arctic Islands — Few Arctic seabird samples have been collected, and except for PCBs in eggs of the Black-legged Kittiwake, organochlorine residues in eggs and tissues were uniformly low. The species that seldom leave the Arctic, such as the Ivory Gull, were as contaminated as species that winter south of the ice, such as the Thick-billed Murre. Long-range

Figure 4
The relative proportions of contaminants in an Atlantic Puffin egg collected at Great Island off the coast of Newfoundland in 1988



atmospheric transport is the major source of organochlorines in the Arctic.

West coast — By the same measure, the Strait of Georgia was the most contaminated area on the British Columbia coast, but levels of the common organochlorines (including PCBs) in eggs from that area were still lower than those found in eggs from the St. Lawrence estuary and the Bay of Fundy. However, levels of polychlorinated dioxins and furans in eggs of Double-crested Cormorant breeding in the strait are high compared to levels detected elsewhere in Canada (Figure 5). The relative amounts of different dioxins and furans present at each site reflect the sources of the contaminants in the

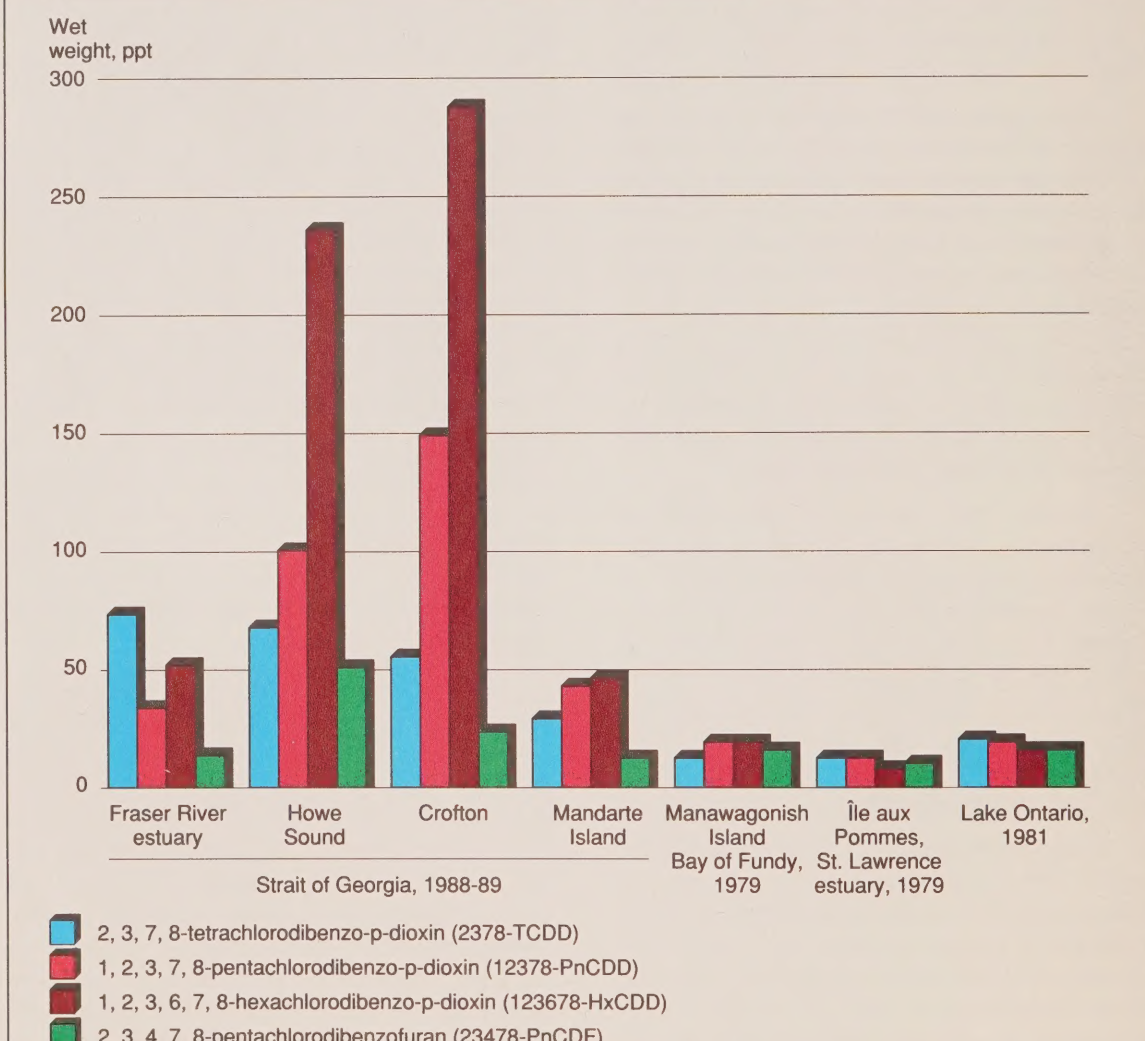
Judging by contaminant levels in seabird eggs, the St. Lawrence estuary is one of the most contaminated marine environments in Canada

eggs. The other species studied in the Strait of Georgia — Pelagic Cormorants and Great Blue Herons — show a similar geographic pattern. Seabirds feeding in estuaries with pulp mills or wood-processing plants were more contaminated overall than those feeding in unindustrialized estuaries.

Compared with the strait, the western coast of Vancouver Island is less contaminated. In the late 1960s and early 1970s, pollution of Hecate Strait and the Queen Charlotte Islands appeared to be relatively minor, but the tests used at that time were not designed to detect dioxins. Contamination seems to have increased in the mid 1980s.

Figure 6 shows the general pattern of PCB contamination of eggs of ocean-feeding seabirds collected in Canadian coastal areas from 1983 to 1988.

Figure 5
Geographic pattern of contamination of the major dioxins and furans in eggs of Double-Crested Cormorants, 1979–89

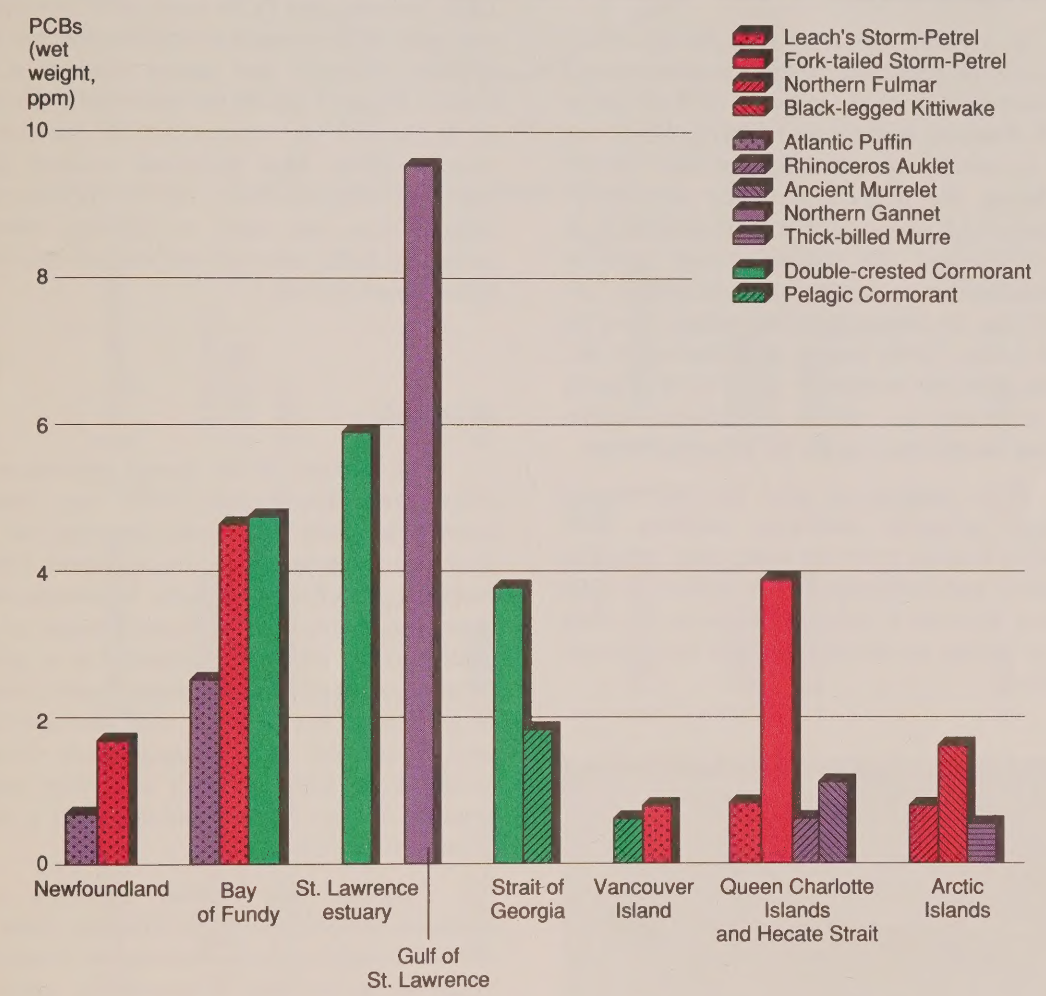


NOTE: Unpublished data from R.J. Norstrom and M. Simon, Canadian Wildlife Service, Environment Canada.

Changes in contaminant levels over time

The overall pattern of change in contaminant levels was quite consistent among all of the coastal regions for which long-term data were available. Since the early 1970s, DDT compounds have declined significantly everywhere, except in the St. Lawrence estuary. On the Atlantic coast, PCBs and dieldrin have declined in eggs of most species, but not always significantly. HCB, HCH, oxychlordane, and heptachlor epoxide levels have fluctuated, but these contaminants are basically just as prevalent now as in the mid-seventies.

Figure 6
The general pattern of PCB contamination in seabird eggs collected between 1983 and 1988



NOTE: Levels in Double-Crested and Pelagic Cormorants, which feed close to shore, tend to reflect pollutants in coastal runoff.

Levels in Leach's Storm-Petrels, Northern Fulmars, Fork-tailed Storm-Petrels, and Black-legged Kittiwakes, which feed at the surface of the open ocean, tend to reflect pollutants that reach the ocean through the atmosphere.

Levels in Atlantic Puffins, Rhinoceros Auklets, Ancient Murrelets, Thick-billed Murres, and Northern Gannets, which are offshore divers, tend to reflect overall marine pollution.

The population of Bonaventure gannets recovered to 21 100 in 1984

On the Pacific coast DDT compounds have declined significantly everywhere. PCBs, however, have declined in the Strait of Georgia but only slightly along the west coast of Vancouver Island. HCB, oxychlordane, dieldrin, and heptachlor epoxide have increased in some species and declined in others.

In the Arctic, four organochlorines (DDE, PCBs, dieldrin, and HCB) declined in most species between 1976 and 1987. However, oxychlordane and heptachlor epoxide increased in most species sampled.

Most biologists conclude that reproductive failures among Bonaventure gannets were the result of eggshell thinning caused by DDE, although dieldrin also may have killed some embryos

In general, the trends in levels of organochlorine pesticides in the Canadian marine environment follow the patterns of their use in North America. In the case of DDT, which was used in immense quantities against forest insects in Canada, the restrictions in the early 1970s resulted in a dramatic decline in levels of DDE in the environment. The continuing high levels of organochlorines in the St. Lawrence estuary are partly due to atmospheric deposition onto the Great Lakes, partly due to mobilization of pollutants from the sediments and soil, and partly due to sewage as well as agricultural and industrial wastes entering the St. Lawrence River.

PCBs continue to enter the environment through industrial discharge, leaching from landfills, leakage from old equipment, industrial accidents and incineration. The decline in PCBs in most locations is probably indicative of a slow global decline in overall levels and local control measures.

Mike Shulz

Stored PCB waste

The recovery of the gannets on Bonaventure Island

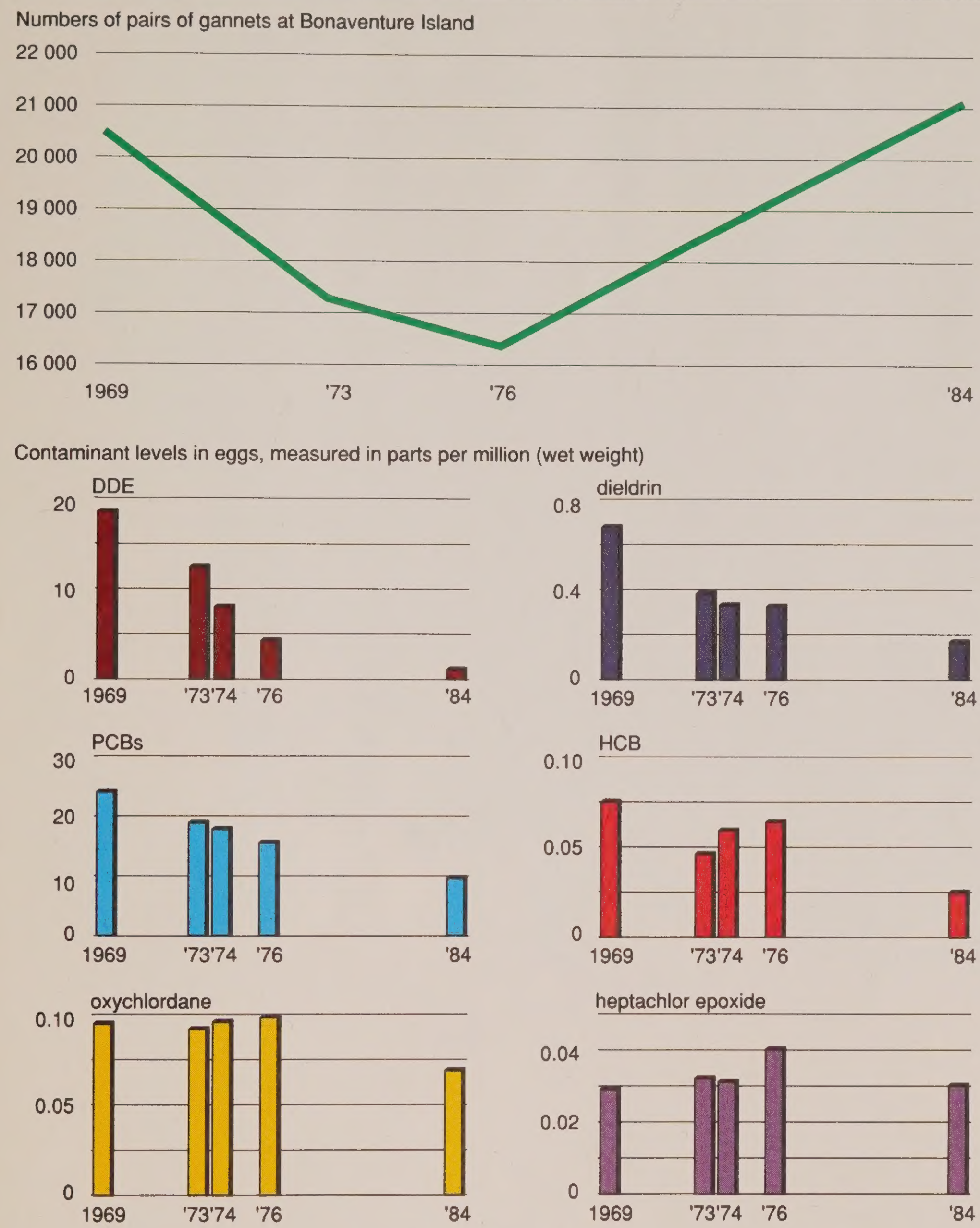
In the 1980s, the Bonaventure colony of gannets began to expand again. In 1984, 75% of the gannets that laid eggs produced an offspring to fledging, compared with a dismal 30% in 1966. A census in 1984 showed that numbers of breeding pairs had risen back to 20 100. The recovery of the population corresponded with lower contaminant levels in the eggs. Scientists have pointed out that the declining levels of DDE, dieldrin, and PCBs since 1968 correspond well with improvements in reproductive success, eggshell thickness, and gannet numbers at the colony. Figure 7 shows the relationship (or lack of it) between six organochlorines and one of these variables. Most biologists conclude from this and other evidence that the reproductive failures were the result of eggshell thinning caused by DDE, although dieldrin also may have killed some embryos.

Outlook

The recovery of the gannet population on Bonaventure Island after DDT was banned demonstrates that regulations governing the use of chemical substances can be successful. This is heartening, but it is not grounds for complacency about the health of seabird populations or the quality of the marine environment as a whole. Large amounts of persistent contaminants remain in the marine environment, new chemical substances continue to be released, and elevated quantities of some naturally occurring metals continue to enter marine food chains as a result of human activities.

Programs that monitor persistent contaminants provide valuable information about the state of Canada's marine environment. Continued vigilance on the part of monitoring agencies, backed up by strict regulation of chemicals suspected of being dangerous, enable Canada to act, domestically and through international agencies, to safeguard the quality of marine food and the health of the marine ecosystem.

Figure 7
Numbers of pairs of gannets at Bonaventure Island, Quebec, 1969-84, and contaminant levels in gannet eggs at the colony, 1969-84



NOTE: Almost all contaminants appeared to decline after 1976. DDE, dieldrin, and PCBs declined significantly between 1969 and 1984. DDE, the main byproduct of DDT, shows the most dramatic decline, probably reflecting the sudden elimination in 1969 of DDT from forest spray programs in Quebec and the Maritime provinces.

HCB and PCBs, which originate mainly from industrial processes, declined more slowly, as these chemicals were slowly phased out.

Oxychlordane and heptachlor did not change significantly over the period sampled. Chlordane, the main source of these two chemicals, was not restricted in Canada until 1978, which may explain the increasing levels between 1969 and 1976.

Large amounts of persistent contaminants remain in marine ecosystems and new chemical substances continue to enter marine food chains

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For further information

Supplementary information on contaminants in seabirds may be obtained from the following address:

Distribution Section
Canadian Wildlife Service
Ottawa, Ontario
K1A 0H3

Information on State of Environment Reporting may be obtained from the following address:

State of the Environment Reporting
Environment Canada
Ottawa, Ontario
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